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Platinum-phosphine-vinylsiloxane complexes.

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A new method for making platinum-phosphine complexes and novel platinum-phosphine-vinylsiloxane complexes are disclosed. These complexes can be used in curable silicone compositions, thus providing curable silicone compositions of greatly enhanced stability at room temperature. The ability of the compositions to cure at elevated temperatures is not significantly compromised.

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1 PLATINUM-PHOSPHINE-VINYLSILOXANE COMPLEXES

5 The present invention relates to an improved method for making platinum-phosphine complexes and to certain platinum-phosphine-vinylsiloxane complexes.

The term platinum-phosphine complexes and platinum-phosphine-vinylsiloxane complexes, as used herein refers to complexes wherein the platinum atom in the complex has a
10 formal oxidation state of zero.

Platinum-phosphine complexes have been known for many years. For example, Malatesta et al., Journal of the Chemical Society, 1957, 1186, disclose the synthesis of platinum-phosphine complexes.

15 Exemplary of known methods for making platinum-phosphine complexes is the reduction of a phosphine-complexed platinumous chloride, said reduction being performed by a mixture of hydrazine, alcoholic potassium hydroxide, and an excess of non-complexed phosphine. Another known method,
20 suitable for making trialkylphosphine complexes of platinum, is the displacement of boronallyl ligands on platinum by phosphines.

Another known method uses platinum-phosphine-olefin complexes as starting materials. An example of this method
25 is the work of Fitch et al., as disclosed in the Journal of Organometallic Chemistry, 1978, 160, 477. Fitch et al. reacted vinylsilanes with platinum-phosphine-olefine complexes wherein the vinylsilanes have the general formula $\text{CH}_2=\text{CHSi}(\text{CH}_3)_y(\text{OC}_2\text{H}_5)_{3-y}$, y having a value of 0, 1, 2 or 3.

Each of these known methods of making platinum-phosphine complexes is fraught with difficulty: yields are
30 low; starting materials are difficult to synthesize, difficult to handle and difficult to obtain; and the

1 reactions are prone to side reactions in the presence of
small amounts of contaminants. For example, small amounts of
water can hydrolyze and cause condensation of the ethoxy-
substituted vinylsilanes of Fitch et al., thus rendering
5 Fitch et al's complexes either less useful, or totally
useless.

It is an object of the present invention to provide
a new and improved method for making platinum-phosphine
complexes. It is a further object to provide a method for
10 making platinum-phosphine-vinylsiloxane complexes. It is
another object to provide novel platinum-phosphine-vinyl-
siloxane complexes. It is yet another object to provide
curable silicone compositions that have enhanced stability at
room temperature.

15 These objects and others are attained by the method
and complexes of the present invention. The method of the
present invention comprises contacting certain phosphines and
platinum-vinylsiloxane complexes with one another in an
oxygen-free environment. The complexes of the present
20 invention are certain platinum-phosphine-vinylsiloxane
complexes.

The present invention relates to a method for
making platinum complexes, said method comprising contacting
a platinum-vinylsiloxane complex with a phosphine selected
25 from the group consisting of R_3P molecules and $R_2P(CH_2)_mPR_2$
molecules wherein each R is selected from the group consist-
ing of monovalent hydrocarbon radicals free of aliphatic
unsaturation and m has a value of 1, 2, or 3, said contacting
being accomplished in a substantially oxygen-free
environment.

30 The present invention further relates to platinum
complexes having the general formula

T_aPtQ_b , wherein in said general formula

1 T is a phosphine selected from the group consisting of
phosphines having the formula R_3P and phosphines having the
formula $R_2P(CH_2)_mPR_2$, each R being a monovalent hydrocarbon
radical free of aliphatic unsaturation and m having a value
5 of 1, 2, or 3;

a has a value of 1 or 2;

Q is a vinylsiloxane; and

b has a value of 1 or 2.

10 The method of the present invention comprises
contacting a platinum-vinylsiloxane complex with a phosphine.

Platinum-vinylsiloxane complexes are well known.
Platinum-vinylsiloxane complexes are the result of reacting
hexachloroplatinic acid with a vinylsiloxane having the
general unit formula

15 $\frac{R'SiO_n}{(4-n)/2}$, wherein each R' is a monovalent
hydrocarbon radical; each n has a value of 1, 2, or 3; there
is at least one R unit in said vinylsiloxane having the
formula $CH_2=CH-$, and there is at least one SiOSi linkage
present in said vinylsiloxane.

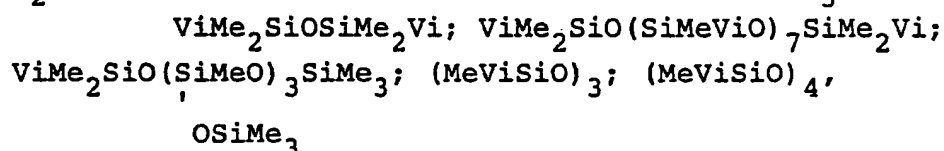
20 Platinum-vinylsiloxane compounds have been
described in US Patent No. 3,419,593, issued December 31,
1968 to David N. Willing, the specification of which patent
further teaches a method for making suitable platinum-
vinylsiloxane complexes. US Patent No. 3,775,452, issued
25 November 27, 1973 to Karstedt also discloses methods for
making suitable platinum-vinylsiloxane complexes.

In general, platinum-vinylsiloxane complexes are
made by contacting a vinylsiloxane with a suitable platinum
compound such as hexachloroplatinic acid. Hexachloroplatinic
acid is well known and widely available commercially.

30 R' in the above general unit formula for the vinyl-
siloxane is a monovalent hydrocarbon radical. Thus, R' can
be an alkyl radical, such as methyl, ethyl, propyl or butyl;

1 an aryl radical such as phenyl or naphthyl; a cycloalkyl
 radical, such as cyclohexyl, cycloheptyl, and the like; an
 alkenyl radical, such as vinyl or allyl; or a cycloalkenyl
 radical, such as cyclohexenyl, cycloheptenyl and the like.
 5 At least one R' of each vinylsiloxane, on average, must be a
 vinyl radical.

The vinylsiloxane can be linear, branched or cyclic
 in structure. Examples of appropriate vinylsiloxanes include
 the following. The term Vi in the following examples of
 10 vinylsiloxanes and in this specification represents the
 $\text{CH}_2=\text{CH}-$ radical; the term Me represents the CH_3- radical.



15 the last two formulae representing cyclosiloxanes; and other
 structures.

Phosphines suitable for use in the method of the
 present invention are selected from those phosphines having
 the formula R_3P , and those phosphines having the formula
 20 $\text{R}_2\text{P}(\text{CH}_2)_m\text{PR}_2$, m having a value of 1, 2, or 3.

R in each of the above formulae is a monovalent
 hydrocarbon radical free of aliphatic unsaturation. Thus, R
 can be an alkyl radical, such as methyl, ethyl, propyl,
 isopropyl, butyl, isobutyl, tertiary butyl, hexyl, heptyl,
 25 and the like. R can also be a cycloalkyl radicals, such as
 cyclopentyl, cyclohexyl, cycloheptyl, and the like. R can
 also be an aryl radical, such as phenyl, naphthyl and the
 like. R can also be an alkaryl radical, such as tolyl,
 xylyl, or mesityl. R can also be an aralkyl radical, such as
 beta-phenylethyl, beta-phenylpropyl and the like.
 30

Phosphines as above described are well known and
 widely available. Moreover, their synthesis is well known in
 the organic chemistry art.

1 Especially preferred phosphines for the method of
the present invention are those in which R is selected from
the group consisting of phenyl, cyclohexyl, and tertiary
butyl radicals.

5 The contacting referred to in performing the method
of the present invention is done by simply exposing the two
reactants to one another as by simply mixing. Mixing can be
accomplished manually, by placing the two reactants in a
single vessel and swirling or shaking. More preferably,
10 mixing is accomplished with a mechanical stirrer or mixer.

 The method of the present invention comprises
contacting the phosphine, as described above, with the vinyl-
siloxane, as described above, in a substantially oxygen-free
environment.

15 By substantially oxygen-free environment it is
meant herein no more than 20 or 30 parts per million by
weight of the environment in which the method of the present
invention is being performed can be O₂, molecular oxygen.
Preferably, the O₂ concentration is less than 20 parts per
20 million.

 While not required, it is most convenient to
perform the method of the present invention in an enclosed
vessel, equipped with a stirrer, under a blanket of inert
gas. Examples of commonly used inert gasses include
nitrogen, helium, and argon. It is also frequently
25 convenient to perform the method of the present invention
with the two reactants dissolved in a suitable solvent.

 Suitable solvents for use in the method of the
present invention are those that will dissolve the two
reactants, and will not appreciably react with either of the
30 two reactants. Many common industrial solvents are suitable.
For example, hexane, heptane, octane, toluene, benzene,
xylene, acetone, and methyl-ethyl ketone are all suitable.

1 Selection of the solvent, if a solvent is used, is not critical.

The method of the present invention can be performed at room temperature, or the temperature can be
5 elevated. If the temperature is elevated, it is necessary to limit the temperature to avoid thermal decomposition of any of the reactants. If a solvent is used, it is desirable to provide a condenser for solvent vapors, and means to return the condensed solvent vapors to the enclosed vessel.

10 The reactants to be contacted with one another are combined in approximately, i.e. $\pm 10\%$, stoichiometric amounts. Thus, if it is desired to produce the complex $\text{Pt}(\text{PPh}_3)_3$, wherein Ph represents the phenyl radical, approximately three moles of PPh_3 are added to each mole of
15 Pt present in the platinum-vinylsiloxane complex. If it is desired to produce the complex $\text{PtP}(\text{tBu})_3(\text{Me}_2\text{ViSi})_2\text{O}$, wherein tBu represents the tertiary butyl radical and Vi represents the vinyl radical, and Me represents the methyl radical, then approximately one mole of $\text{P}(\text{tBu})_3$ are added to each mole of
20 Pt present in a platinum-vinylsiloxane complex wherein the vinylsiloxane is $(\text{Me}_2\text{ViSi})_2\text{O}$.

The reaction in the method of the present invention is fairly rapid, and is generally completed in less than an hour. Simple routine experimentation can be used to
25 determine optimum reaction conditions or reaction times, if such are desired.

If it is desired that platinum-phosphine-vinylsiloxane complexes be produced in the method of the present invention, phosphines having relatively sterically large groups should be used, e.g. tertiary butyl or cyclohexyl
30 groups. Conversely, if a platinum-phosphine complex is desired, phosphines substituted with relatively sterically small groups should be used, e.g. methyl or ethyl.

1 Compositions of the present invention have the
general formula

T_aPtQ_b , wherein

5 T is a phosphine selected from the group consisting of
phosphines having the formula R_3P and phosphines having the
formula $R_2P(CH_2)_mPR_2$, each R being a monovalent hydrocarbon
radical free of aliphatic unsaturation and m having a value
of 1, 2, or 3;

a has a value of 1 or 2;

10 Q is a vinylsiloxane; and

b has a value of 1 or 2.

The platinum in the above general formula will have
either 3 or 4 complexation sites. Since the phosphine can be
a monodentate ligand of the form R_3P or a bidentate ligand of
15 the form $R_2P(CH_2)_mPR_2$, and the vinylsiloxane can also be a
monodentate or a multidentate ligand, it will be noted that
the sum of a plus b can have a value of 2, 3, or 4.

Particularly preferred complexes of the present
invention are

20 $Pt(P(C_6H_5)_3)_3$;
 $Pt((C_6H_5)_2PCH_2CH_2P(C_6H_5)_2)_2$;
 $Pt(C_6H_{11})_3P((CH_2=CH)(CH_3)_2Si)_2O$; and
 $PtC(CH_3)_3P((CH_2=CH)(CH_3)_2Si)_2O$.

The platinum complexes of the present invention are
25 useful as catalysts for hydrosilylation reactions; as
catalysts for hydrogenation of unsaturated organic compounds
or polymers; as catalysts for the isomerization of olefins;
as catalysts for the oligomerization of acetylene and other
alkynes; and in many other applications which require a
platinum catalyst.

30 The platinum complexes of the present invention
resulting from the method of the present invention are

1 especially useful as curing catalysts for curable silicone compositions comprising

- 1) a silicone polymer having at least one unit selected from the group consisting of $\text{CH}_2=\text{CH}-\text{Si}^-$ units and $^-\text{SiOH}$ units;
- 5 2) a silicone polymer having at least one ^-SiH unit; and
- 3) a platinum complex formed by contacting a phosphine with a platinum-vinylsiloxane complex.

A curable silicone composition as described above is made by simply mixing the appropriate polymers and
10 platinum complex together. Simple mixing is accomplished by mixers, such as Myers® mixers, sigmoid blade mixers, three-roll mills, two-roll mills, Baker Perkins® type mixers, and other known mixers.

Generally from 1 to 99 parts by weight of Component
15 (1), from 1 to 99 parts by weight of Component (2), and a catalytically effective amount of the platinum complex are used. By catalytically effective amount it is meant herein an amount sufficient to allow the curable composition to be cured in a reasonable amount of time, such as an hour or
20 less, at a reasonable elevated temperature, such as 35°C or higher.

Catalytically effective amounts of the platinum complex of the present invention vary from 1 part per million-
by weight of platinum metal to 0.1% by weight of platinum
25 metal.

More preferably, the amounts of Components (1) and
(2) are selected so that approximately equimolar amounts of
 ^-SiH on the one hand and $^-\text{SiCH}=\text{CH}_2$ or $^-\text{SiOH}$ on the other hand
are used.

A curable composition as described above is a
30 useful coating material, such as a paper release coating. If a reinforcing filler, such as amorphous silica, is added to

1 the curable composition, a useful elastomer will result upon cure.

5 The platinum complexes produced by the method are useful catalysts for both filled and unfilled curable silicone compositions.

10 The following examples are here presented to further teach the method of the present invention and the use of the products of the present invention. All parts and percentages in the examples are by weight unless otherwise specified.

Characterization Methods

The products of the method of the present invention were characterized by the following methods:

15 Yield: Yields were determined by dividing the weight of the product actually obtained by the weight of product which would result from complete reaction and recovery of product, and multiplying the result of this division by 100%.

20 Elemental Analysis: Carbon and hydrogen percentages were determined by the combustion method. The complexes being analyzed were quantitatively burned in oxygen, and the resulting weights of CO_2 and H_2O were determined. These weights were used to calculate the percentages of carbon and hydrogen originally present in the complex.

25 Phosphorous, platinum and silicon analyses reported herein were done by atomic absorption spectroscopy, which is a well known method for determining these elements quantitatively.

Yields reported herein were calculated on the basis of the amounts of phosphine in the reaction mixture.

30 The following test procedures were used to evaluate cured films in the following examples.

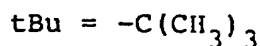
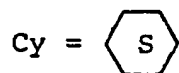
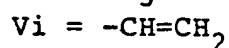
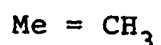
Smear - Smear of a coating was evaluated by lightly rubbing the cured coating with a finger. A wholly cured coating will

1 not change in appearance upon rubbing. No change in the
appearance in the smear test is recorded in the following
examples as "no smear."

5 Rub-off - Rub-off of a coating was evaluated by vigorously
rubbing the cured coating with a finger. The result "no
ruboff" indicates that the coating could not be removed in
this manner. The result "ruboff" indicates that the coating
was easily removed.

10 Migration - Migration was evaluated herein by: first,
adhering a strip of standard adhesive-coated tape to the
cured coating by firmly pressing the side coated with
adhesive to the cured coating; second, removing the tape from
the cured coating by peeling the tape up; third, doubling the
removed tape back upon itself with the adhesive coated side
15 adhering to itself; and fourth, comparing the force required
to peel the doubled tape to the force required to peel a
freshly prepared, similarly doubled tape which had never been
adhered to the coating. If the force required is
substantially the same, no migration of the coating or
20 components thereof has occurred. This result is recorded as
"no migration." Total loss of adherence indicates that
migration of coating components has taken place. This result
is recorded as "migration."

25 The following terms are assigned the following
meanings in the examples for the sake of brevity:



1 Example 1

1.35 g of platinum - $(\text{Me}_2\text{ViSi})_2\text{O}$ complex mixture consisting of the complex dissolved in $(\text{Me}_2\text{ViSi})_2\text{O}$ and higher oligomers consisting of (Me_2SiO) units and $\text{Me}_2\text{ViSiO}_{3/2}$ units, containing 4.02% platinum, were added to a solution consisting of 0.3 g of PPh_3 dissolved in 10 ml of pentane, all of the above ingredients being confined to a closed vessel under a nitrogen blanket. Yellow crystals rapidly precipitated. These yellow crystals were filtered, and washed with pentane. Residual pentane was removed by exposing the yellow crystals to reduced pressure for several minutes. The calculated yield was 84.7%.

Elemental analysis for carbon and hydrogen was consistent with the structure

15 $\text{Pt}(\text{PPh}_3)_3$:

	<u>theory</u>	<u>found</u>
% carbon	66.06	66.34
% hydrogen	4.59	5.03

20 Example 2

1.35 g of the platinum-vinylsiloxane complex mixture used in Example 1 were added to a solution consisting of 0.24 g of $\text{Ph}_2\text{PCH}_2\text{CH}_2\text{PPh}_2$ dissolved in 10 ml of toluene. Said addition was accomplished in an enclosed vessel under a nitrogen blanket. The above reactants were mechanically mixed for 30 minutes, after which time the toluene was removed under reduced pressure. The residue was a yellow solid. This yellow solid was dissolved in pentane, then isolated by the procedure of Example 1. Yield was 72.4%. Elemental analysis was consistent with the structure

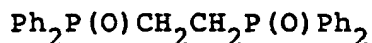
30 $\text{Pt}(\text{Ph}_2\text{PCH}_2\text{CH}_2\text{PPh}_2)_2$

1		<u>theory</u>	<u>found</u>
	% carbon	62.90	61.29
	% hydrogen	4.80	5.40

Comparison to Example 2

5 The same reactants used in Example 2 were reacted together, in acetone, with no steps being taken to exclude oxygen from the reaction environment.

 The resulting product had a melting point of 269°C - 270°C, as compared to a published value of 273°C - 274°C for the compound



 Elemental analysis was consistent with this structure:

		<u>theory</u>	<u>found</u>
15	% carbon	72.50	71.40
	% hydrogen	5.60	5.76
	% phosphorous	14.40	14.40

 Thus, it is seen that failure to perform the method of the present invention in a substantially oxygen-free environment results in an oxidized phosphine rather than a platinum complex.

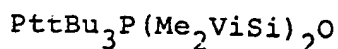
Example 3

 40 g of the platinum-vinylsiloxane complex mixture used in Example 1 and 1.80 g of $\text{P}(\text{tBu})_3$ were heated together, with mixing, in an enclosed vessel, under a nitrogen blanket, to a temperature of 65°C. This temperature was maintained for 5 minutes, after which time the mixture was allowed to cool to room temperature.

 A white solid separated, which solid was filtered, washed with $(\text{Me}_2\text{VSi})_2\text{O}$, and the residue was exposed to reduced pressure to remove volatile substances. The product was obtained in a yield of 79.4%, and had a melting point of 145°C - 147°C.

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The product was subjected to X-ray structural analysis, which analysis proved the structure to be



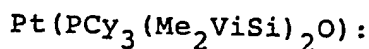
Elemental analysis was consistent with the above structure:

	<u>theory</u>	<u>found</u>
% carbon	41.16	41.23
% hydrogen	7.72	7.57
% phosphorous	5.32	5.49
% silicon	9.61	9.50
% platinum	33.45	33.22

Example 4

80 g of the platinum-vinylsiloxane complex used in Example 1 were heated with 5.0 g of PCy_3 under a nitrogen blanket, with mixing. After a temperature of 85°C had been attained and held for 5 minutes, the mixture was allowed to cool. A white solid separated, which solid was treated by the procedure of Example 3. The product was obtained at a yield of 63.2%, and had a melting point of $188^\circ\text{C} - 189^\circ\text{C}$.

Elemental Analysis was consistent with the structure



	<u>theory</u>	<u>found</u>
% carbon	47.20	48.20
% hydrogen	7.72	7.95
% phosphorous	4.60	4.50
% silicon	8.47	8.75

Example 5

0.25 g of the complex produced in Example 4 were dissolved in sufficient toluene to produce a 0.71% platinum solution.

1 The following components were mixed together to
form a curable silicone composition:

1) 67.9 g of a polymer having the average formula

$\text{ViMe}_2\text{SiO}(\text{Me}_2\text{SiO})_{135}\text{SiMe}_2\text{Vi}$; and

5 0.63 g of methylvinylcyclsiloxanes;

2) 3.22 g of a mixture consisting of

a) 41.67 parts of a polymer having the
average formula

$\text{Me}_3\text{SiO}(\text{MeHSiO})_{35}\text{SiMe}_3$; and

10 b) 58.33 parts of a $(\text{Me}_2\text{SiO})/(\text{MeHSiO})$
copolymer having a viscosity of 5
centistokes at 25°C.

3) 1.29 g of the 0.71% platinum solution.

15 The viscosity of this mixture was monitored as a
function of time. Additionally, the time required to cure a
thin film at 130°C was determined periodically. The criteria
for cure were no smear, no ruboff, and no migration. See
Table 1.

20 Table 1
Cure Stability

	<u>Time at 25°C</u> <u>(hours)</u>	<u>Viscosity</u> <u>(Centistokes at 25°C)</u>	<u>Minimum Cure</u> <u>Time at 130°C</u>
	0	304	70 seconds
	5	308	--
25	7.5	308	--
	24	344	75 seconds
	32	308	--
	64	420	--
	82	580	--
30	154	gelled	--

1 Comparison to Example 5

 The procedure of Example 5 was repeated with a platinum-vinylsiloxane complex instead of a complex of the present invention. This mixture gelled in 30 minutes.

5 The procedure of Example 5 was then repeated with a platinum-vinylsiloxane complex instead of a complex of the present invention. This time 2.44 parts of the inhibitor 3,5-dimethyl-1-hexyne-3-ol were included. The results of evaluation of this comparison are found in Table II.

10 Table 2
 Cure Stability

	<u>Time at 25°C</u> <u>(hours)</u>	<u>Viscosity</u> <u>(centistokes at 25°C)</u>	<u>Minimum Cure</u> <u>Time at 82°C</u>
	0	368	60 seconds
15	5	476	--
	7	516	--
	12	gelled	--

 Thus, it is seen that the complexes of the present invention greatly enhance effective life of a curable
20 silicone composition at room temperature without seriously compromising the ability to cure at elevated temperatures.

25

30

35

1 Claims:

5 1. A method for making platinum complexes, said method comprising contacting a platinum vinylsiloxane complex with a phosphine selected from the group consisting of R_3P molecules and $R_2P(CH_2)_mPR_2$ molecules wherein each R is selected from the group consisting of monovalent hydrocarbon radicals free of aliphatic unsaturation and m has a value of
10 1, 2, or 3, said contacting being accomplished in a substantially oxygen-free environment.

2. Platinum complexes having the general formula
15 T_aPtQ_b
wherein, in said general formula T is a phosphine selected from the group consisting of phosphines having the formula R_3P and phosphines having the formula $R_2P(CH_2)_mPR_2$, each R being a monovalent hydrocarbon radical free of aliphatic
20 unsaturation and m having a value of 1, 2, or 3;
 a has a value of 1 or 2;
 Q is a vinylsiloxane; and
 b has a value of 1 or 2.

25 3. Platinum complexes as claimed in claim 2 wherein Q is $((CH_3)_2CH_2=CHSi)_2O$, a has a value of 1, and b has a value of 1.

30 4. Platinum complexes as claimed in claim 3 wherein each R is a phenyl radical.

1 5. Platinum complexes as claimed in claim 3
wherein each R is a cyclohexyl radical.

5 6. A platinum complex as claimed in claim 5 having
the formula $\text{PtP}(\text{C}_6\text{H}_{11})_3[(\text{CH}_3)_2\text{CH}_2=\text{CHSi}]_2\text{O}$.

10 7. Platinum complexes as claimed in claim 3
wherein each R is a tertiary butyl radical.

15 8. A platinum complex as claimed in claim 7 having
the formula $\text{PtP}[\text{C}(\text{CH}_3)_3]_3[(\text{CH}_3)_2\text{CH}_2=\text{CHSi}]_2\text{O}$.

20 9. A curable silicone composition comprising
1) from 1 to 99 parts of a silicone polymer having at
least one unit selected from the group consisting of
 $\text{CH}_2=\text{CHSi}\equiv$ units and $\text{HOSi}\equiv$ units;

2) from 1 to 99 parts of a silicone polymer having at
least one $\text{HSi}\equiv$ unit; and

3) a catalytically effective amount of a platinum
complex having the general formula

T_aPtQ_b , wherein, in said general formula

25 T is a phosphine selected from the group consisting of
phosphines having the formula R_3P and phosphines having the
formula $\text{R}_2\text{P}(\text{CH}_2)_m\text{PR}_2$, each R being a monovalent hydrocarbon
radical free of aliphatic unsaturation and m having a value
of 1, 2, or 3;

30 a has a value of 1 or 2;

Q is a vinylsiloxane; and

b has a value of 1 or 2.

the above parts being parts by weight.